

appends outer parity of sixteen bytes to a 192-byte column in the column direction. The outer-error-correction encoded columns, each being 208-byte long, are then stored in a buffer of the RS encoder.

5 After outer-error-correction encoding of 172 columns is completed, 172 columns become arranged sequentially in the buffer. Then, for every row of the data block in the buffer, inner-error-correction encoding is performed sequentially by the PI encoder by appending inner parity of ten symbols to a
10 172-symbol row in the row direction.

In this way, the RS encoder produces the ECC block shown in FIG. 1. As a result, the ECC block is 37,586 bytes in size ($182 \times 208 = 37,586$). Each symbol of the ECC block is then ESM-modulated so as to be written onto a storage medium like
15 DVD.

The error correction encoding method using ECC block structure shown in FIG. 1 has been devised based on data density of current optical disks like DVD. It is, however, expected that for next-generation storage media of higher data density than
20 DVD the error correction encoding method of the conventional art is vulnerable to burst errors.

It will be likely that next-generation high-density storage medium, the density of which is twice as high as DVD, has two times more channel bit errors than DVD for a scratch
25 of the same size. Therefore, the development of an effective error correction encoding method is required to enhance the capability of correction of burst errors on next-generation high-density storage media.

SUMMARY OF THE INVENTION

30 A general objective of the present invention is to solve

the above-mentioned problems and to provide an error correction encoding method of improving the error correction capability for high-density storage media and reading/writing devices for the high-density storage media.

5 The error correction encoding method for a high-density storage medium according to the present invention, comprises the steps of: arranging sequential input data so as to form a plurality of data blocks of a predetermined matrix form, the plurality of data blocks being made sequentially, appending
10 outer parity of a predetermined size to each column of each data block in the column direction, appending inner parity of a predetermined size to each row of each of the outer-parity-encoded data block in the row direction, reordering rows including outer parity so as to insert them separately into the
15 other rows including no outer parity for each of the outer- and inner-parity-encoded data blocks, and reading out rows in the same order in the resulting data blocks sequentially and writing them to said storage medium on row-by-row basis.

20 The method of the present invention is characterized in that it can be used in error correction for higher density storage media than DVD and reading/writing apparatus for higher density storage media. Also, the error correction encoding method according to the present invention is easy to implement on existing DVD recorders, thereby enabling to develop players
25 capable of reproducing storage media of two types, or DVD and next-generation high-density storage medium, with less hardware development and production cost.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are included to provide
30 a further understanding of the invention, illustrate a

preferred embodiment of this invention, and together with the description, serve to explain the principles of the present invention.

In the drawings:

FIG. 1 shows an ECC block structure using a two-dimensional Reed-Solomon code;

FIG. 2 is a block diagram of a data writing apparatus embodying the present invention;

FIG. 3 shows formats of data blocks that are used in the error correction encoding method according to the present invention;

FIG. 4 shows data blocks of FIG. 3 after outer- and inner-error-correction encoding; and

FIG. 5 illustrates a way in which two data blocks shown in FIG. 4 are written to a storage medium.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiment of the present invention will be described in detail referring to the accompanying drawings.

FIG. 2 depicts a block diagram of a data writing apparatus embodying the present invention. As shown in FIG. 2, the data writing apparatus comprises a controller 10 for controlling constituting components; a first buffer 20 for arranging input digital data that are sequentially inputted so as to form data blocks of a predetermined matrix form (hereinafter, unit block), and producing a pair of unit blocks, i.e., a first unit block and a second unit block, in the input order, under control of controller 10; a second buffer 30 for temporarily storing, under control of controller 10, the pair of unit blocks transmitted from the first buffer 20; an error correction encoding unit 100 that consists of an outer parity (PO) encoder

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40 for appending outer parity of a predetermined number of bytes, in the column direction, to each column of the pair of unit blocks and an inner parity (PI) encoder 50 for appending inner parity of a predetermined number of bytes, in the row direction, to each row of the pair of the outer-parity-encoded unit blocks that have been temporarily stored in second buffer 30; and a data writer 60 for reading out rows in the same order in the pair of the resulting unit blocks sequentially from second buffer 30 and writing the read-out rows into a high-density storage medium on row-by-row basis under control of controller 10.

With reference to the data writing apparatus of FIG. 2, the error correction encoding method according to the present invention will be described below in detail.

15 Digital data sequentially inputted to first buffer 20 are arranged in a manner that a pair of unit blocks, $U(i,j)$ and $V(i,j)$ shown in FIG. 3 are formed in first buffer 20, in the order as stated, under control of controller 10. Each unit block has 192 rows, each being 172-byte long. That is, each unit block 20 is 33,024 bytes (172×192 bytes) in size. A pair of unit blocks, $U(i,j)$ and $V(i,j)$ are formed by arranging input data of 66,048 bytes. Specifically, letting row and column position in an unit block be represented by i and j , where $0 \leq i \leq 191$ and $0 \leq j \leq 171$ and an order in which bytes in the input data of 33,024 25 bytes are sequentially inputted be represented by b , where $0 \leq b \leq (192 \times 172) - 1$, each unit block is made by using the equations: $i = b / 172$ and $j = b - (172 \times i)$.

Once generation of a pair of unit blocks, $U(i,j)$ and $V(i,j)$ are completed, the two unit blocks are transmitted from 30 first buffer 20 to second buffer 30 under control of controller 10. On the other hand, controller 10 repeatedly controls first

buffer 20 such that another pair of unit blocks are formed in first buffer 20 by arranging the sequential input data.

First, the first unit block $U(i,j)$ in second buffer 30 is outer-error-correction encoded by PO encoder 40. That is, for every column of $U(i,j)$, PO encoder appends outer parity of sixteen bytes to a 192-byte column in the column direction. Then, for every row of the resulting $U(i,j)$, which has 208 rows, PI encoder 50 appends inner parity of ten bytes to a 172-byte row in the row direction. The same error-correction-encoding is carried out for second unit block $V(i,j)$. FIG. 4 shows a pair of RS-encoded unit blocks, each resulting in (182×208) bytes in size.

After that, for encoded unit blocks $U(i,j)$ and $V(i,j)$ shown in FIG. 4, the sixteen rows including outer parity are reordered in order to insert them separately among the other 192 rows including no outer parity in such a way that one row including outer parity is positioned after every other twelve rows including no outer parity. By doing this, outer parities are prohibited from being damaged at a burst.

As shown in FIG. 5, the resulting unit blocks $U(i,j)$ and $V(i,j)$ are combined in such a manner that rows in the same order correspond to each other. Then, sync data is generated and inserted into appropriate positions of each row of the combined block. Finally, under control of controller 10 data writer 60 reads out data in one row of the combined block at a time from second buffer 30, as shown in FIG. 5 and modulates and writes the row including 364-byte data and inserted sync data onto high-density storage medium 70 sequentially. Such writing operation is repeated until 208 rows of the combined block are written onto high-density storage medium 70.

To be more specific, let (row, column) positions in the two unit blocks, $M(p,q)$ and $N(r,t)$ shown in FIG. 5 that